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FOR

**METHOD TO PRODUCE DATA CELL REGION AND SYSTEM REGION  
FOR SEMICONDUCTOR MEMORY**

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# METHOD TO PRODUCE DATA CELL REGION AND SYSTEM REGION FOR SEMICONDUCTOR MEMORY

## RELATED APPLICATION DATA

This patent is a divisional application of U.S. serial number 09/233,653 filed on  
5 January 19, 1999. Moreover, this patent claims priority to Japanese Application No.  
P10-008170, filed January 20, 1998. Both of these applications are incorporated by  
reference to the extent permitted by law.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

10 The present invention includes memory and an information apparatus which  
may be applied, for example, to a read only memory, random access memory, or to an  
apparatus utilizing these memories. The present invention also includes a memory  
which may increase its capacity with a simplified process. Moreover, the invention  
includes an information apparatus utilizing this memory by generating data cell region  
15 with the process other than that used to generate the system region to control data cells.

### 2. Description of the Related Art

Memory may be thought of as any device that can hold data in a machine-  
readable format. Moreover, a semiconductor may be viewed as material, typically  
crystalline, which allows current to flow under certain circumstances and may be used  
20 to create various integrated circuits. Most memory devices used in the computer  
industry are built from semiconductor integrated circuits.

In a conventional semiconductor memory such as represented by a dynamic  
random access memory (DRAM), etc., data cells may be formed by a charge  
accumulation mechanism and are arranged in the shape of a matrix. Access is made to  
25 these data cells from a system region. Thereby, data may be written by accumulating



## SUMMARY OF THE INVENTION

In view of overcoming such disadvantage, the present invention produces the data cell region and system region with different manufacturing processes.

When the data cell region and system region are manufactured with the  
5 processes of the invention, the data cell region and system region may be manufactured with the most applicable manufacturing processes and thereby a large capacity memory may be generated with a more simplified overall process.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view showing a memory chip as a first embodiment of the present invention.

Fig. 2 is a plan view showing a memory substrate of Fig. 1.

5 Fig. 3 is a block diagram showing a system region to be arranged on the memory substrate of Fig. 2.

Figs. 4A to 4C are signal waveform diagrams for explaining operations of a sense amplifier of Fig. 3.

10 Figs. 5A to 5E are cross-sectional views for explaining generation of word lines of data cell region of Fig. 1.

Fig. 6 is a plan view for explaining electrodes for connecting word lines to the memory substrate.

Fig. 7 is a cross-sectional view for explaining a generation process of an interlayer insulating layer.

15 Figs. 8A to 8E are cross-sectional views for explaining generation of bit lines of data cell region of Fig. 1.

Fig. 9 is a cross-sectional view showing a chip as a second embodiment of the present invention.

20 Figs. 10A to 10E are cross-sectional views for explaining the generation of word lines in the data cell region of Fig. 9.

Figs. 11A to 11C are cross-sectional views for explaining the subsequent processes of Figs. 10A to 10E.

Fig. 12 is a plan view for explaining a memory chip as a third embodiment of the present invention.

Fig. 13 is a plan view showing the bit lines in comparison with Fig. 12.

Fig. 14 is a plan view for explaining overlapping condition of the word lines and bit lines.

Fig. 15 is a plan view for explaining overlapping condition of the word lines and bit lines.

Fig. 16 is a cross-sectional view for explaining a memory chip as a fourth embodiment of the present invention.

Fig. 17 is a perspective view showing a data cell substrate to be applied to a memory chip as a fifth embodiment of the present invention.

Fig. 18 is a cross-sectional view for explaining evaporation in generation of word lines.

Figs. 19A and 19B are, respectively, a plan view and a cross-sectional view showing the word lines generated by the evaporation of Fig. 18.

Figs. 20A to 20C are cross-sectional views showing generation processes of word lines in the data cell substrate to be applied to a memory chip as the sixth embodiment of the present invention.

Fig. 21 is a perspective view showing a data cell substrate to be applied to a memory chip as a seventh embodiment of the present invention.

Fig. 22 is a perspective view showing generation process of word lines by means of data cell substrate of Fig. 21.

Fig. 23 is a perspective view showing generation process of bit lines by means of data cell substrate of Fig. 21.

Fig. 24 is a perspective view showing relationship among word lines, bit lines and data cell by means of data cell substrate of Fig. 23.

Fig. 25 is a perspective view showing a data cell substrate to be applied to a memory chip as an eighth embodiment of the present invention.

Fig. 26 is a perspective view showing generation process of word lines by means of data cell substrate of Fig. 25.

5 Fig. 27 is a perspective view showing generation process of insulation layer in data cell substrate of Fig. 25.

Figs. 28A and 28B are cross-sectional views showing the portions cut at the lines A-A and B-B of Fig. 27.

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## DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention will be explained with reference to the accompanying drawings.

### (1) First embodiment

#### 5 (1-1) Structure of the first embodiment

Fig. 1 is a cross-sectional view showing a memory chip of a random access memory (RAM) as a first embodiment of the invention. A memory of this embodiment is formed by accommodating this memory chip 1 into a package. This memory chip 1 is formed by disposing a data cell region 3 on a memory substrate 2.

10 Namely, this data cell region 3 is structured, in Fig. 1, by a plurality of word lines 4 extending in the direction across the paper surface in the vertical direction, a plurality of bit lines 5 extending at right angles (orthogonal) to the word lines 4, diodes 6 formed by stacking of layers between the word lines 4 and bit lines 5 almost at the intersecting points of the word lines 4 and bit lines 5 and recording layers 7.

15 Thereby, the data cell region 3 arranges in the shape of matrix data cells formed by diode 6 and recording layer 7. A data cell may be accessed with the word line 4 and bit line 5. This recording layer 7 is formed of germanium antimony tellurium (GeSbTe) and may be composed of a binary compound of at least one of oxygen, sulfur, selenium, and tellurium to create a chalcogenide semiconductor material. The  
20 recording layer 7 also may be formed of TeAsSiGe, GeTeSSb or AgInSbTe, etc. composed of such chalcogenide semiconductor. Moreover, the data cell region 3 is insulated by the interlayer insulating layer 8 between the word lines 4, between bit lines 5 and between data cells and it is protected as a whole by a protection layer 9.



The data cell region 3 includes, through a work line generating process, the work lines 4, diodes 6 and recording layer 7 on the memory substrate 2 and thereafter generates the interlayer insulating layer 8 between the word lines 4 by the interlayer insulating film layer generating process. With the subsequent bit line generating process, the bit lines 5 are generated and, after the interlayer insulating layer 8 is generated by the interlayer insulating layer film generating process between the bit lines 5 and between data cells, the protection layer 9 is generated.

Fig. 2 is a plan view showing a memory substrate 2. The memory substrate 2 includes, through a semiconductor process, a system region 2A by peripheral circuits at the center of substrate 2 of almost rectangular shape and also arranges the bit line electrode pad 2B, word line electrode pad 2C and external connection electrode pad region 2D surrounding the system region 2A.

The external connection electrode pad region 2D includes an external connection electrode pad connected to the system region 2A and each external connection electrode pad is connected, for example, to a terminal of package by the bonding method. The bit line electrode pad 2B connects the system region 2A and bit lines 5 of data cell region 3 and the word line electrode pad 2C connects the system region 2A and the word lines 4 of data cell region 3.

The memory substrate 2 may be manufactured by using comparatively old facilities among the ultra-fine manufacturing apparatus and ultra-fine manufacturing facilities to be applied to the semiconductor processes because the pattern width of wiring patterns is wider than the wiring pattern width of the data cell region 3.

As shown in Fig. 3, the system region 2A is provided with a row address buffer 11 and a column address buffer 12 to hold the address signal 60 input via the external

connection electrode pad 2D as separated into the row address and column address corresponding to the structure of the data cell region 3. System region 2A also may include a row address decoder 13 and a column address decoder 14 to select the word line 4 and bit line 5 of the data cell region 3 by decoding the address held respectively in the row address buffer 11 and column address buffer 12.

The system region 2A also is provided with an input circuit 16 to drive a sense amplifier 15 with the data 62 input via the external connection electrode pad 2D to record the data 62 to the data cell selected by the row address decoder 13 and column address decoder 14 and an output circuit 17 to drive, on the contrary, the sense amplifier 15 to read and output the data from the data cell selected by the row address decoder 13 and column address decoder 14. The input circuit 16 and output circuit 17 execute these operations with the recording/reproducing control signal 64 input via the external connection electrode pad 2D.

The sense amplifier 15 applies the predetermined voltage, as shown in Fig. 4A, at the time of recording the data of logic 1 under the control of the output circuit 17, so that a heavier current ( $I_1$ ) flows within a short period ( $t_1$ ) in the recording layer 7 of the memory chip selected by the row address decoder 13 and column address decoder 14. This rapidly heats a localized address area of recording layer 7 to an uncrystallized state. At the end of the short period of time, the sense amplifier 15 rapidly sets GeSbTe to a lower temperature after setting it to the temperature higher than the predetermined temperature to fix the recording layer 7 in the uncrystallized (amorphous) condition.

On the contrary, as shown in Fig. 4B, the predetermined voltage is applied, on the occasion of the recording the data of logic 0 under the control of the output circuit 17, so that a current ( $I_2$ ) lower than that for recording the data of logic 1 flows for a

longer period ( $t_2$ ) in the recording layer 7 of the memory chip 1 selected by the row address decoder 13 and column address decoder 14. Thereby, after GeSbTe is set to the temperature higher than the predetermined temperature, temperature is gradually lowered to crystallize the recording layer 7.

Moreover, during the data reproducing condition, as shown in Fig. 4C, the predetermined voltage is impressed to detect a current  $I_3$  flowing to the recording layer 7 with a sense amplifier 15 and this current  $I_3$  is output through binary discrimination.

Thereby, the desired data may be recorded or recorded data may be reproduced through the resistance values of the recording layer 7 which are different under the amorphous condition and crystallized condition. In other words, recorded data information may be represented by a set of resistance values within the recording layer 7, where these resistance values are a function of localized crystal structures within the recording layer 7. A known, predetermined voltage may be passed over one resistance value to generate a current  $I$ . Current  $I$  travels to sense amplifier 15 where current  $I$  is detected and passed onto output circuit 17. Output circuit 17 employs binary discrimination to pass the recorded data information to the external connection electrode pads 2D.

Figs. 5A-E are cross-sectional views of a memory chip 1 for explaining the word line 4 generation process. In this embodiment, the data cell region 3 forms a metal layer 4A to the entire surface of the memory substrate 2. Here, the metal layer 4A is a metal thin film of aluminum, gold, copper, tungsten, titanium, nickel, polysilicon or silicide, etc. and may be formed by the thin film forming method such as sputtering, evaporation or Chemical Vapor Deposition (CVD), etc. (Fig. 5A.) The

metal layer 4A may be generated with a kind of metal material or with a plurality of kinds of metal materials.

Subsequently, in the data cell region 3, after a P-type amorphous silicon is deposited on the metal layer 4A by the low temperature CVD process, etc., the N-type amorphous silicon is deposited thereon. Moreover, annealing is performed to generate pn-silicon layer 6A of the polycrystal silicon. Thereafter, a recording film 7A is deposited on the data cell region 3 through the thin film generating technique such as sputtering, evaporation and CVD, etc.

Subsequently, in the data cell region 3, the recording film 7A is coated with an ultraviolet-setting resin 20 (Fig. 5B), a stamper 21 is pressed (Fig. 5C), after the ultraviolet-setting resin 20 hardened under this condition as resin 20A, the stamper 21 is peeled. Here, the stamper 21 is formed like a sheet, for example, of nickel material in the thickness of 0.1 to 0.4 [mm] to have flexibility for bending, forming the recessed groove at the pressing surface corresponding to the word line 4. Thereby, the protruded area 66 and recessed area 68 of stamper 21 of data cell region 3 are transferred by the so-called 2P (Photo-Polymerized) method and thereby protruded 70 and recessed 72 areas are formed in the ultraviolet-setting resin 20A on the recording film 7A so that the word line 4 becomes thick. In place of the ultraviolet-setting resin 20, a thermo-setting resin or photoresist also may be applied. The stamper 21 also may be structured with glass, plastic and metal materials. Thereby, the stamper 21 forms the reference member 20A having the protruded 70 and recessed 72 areas that correspond to the wiring pattern eventually formed as the word line 4.

On the occasion of generating the protruded 70 and recessed 72 areas corresponding to the word line 4 by pressing the stamper 21 as explained above, in the

area overlapping with the word line electrode pad 2C (Fig. 2), as shown in the enlarged pressing surface of Fig. 6, the recessed area 72 is formed at the pressing surface so that the protruded area 70 is formed corresponding to the shape of the word line electrode pad 2C. Here, the word line electrode pad 2C is formed with remarkably loose period in comparison with the word line 4 and in the larger area.

Therefore, as seen in Fig. 5D, the data cell area 3 is processed at the protruded area 70 of the ultraviolet-setting resin 20A leaving the metal layer 4A, pn silicon layer 6A and recording film 7A to structure the word line 4 and diode 6 of Fig. 5E. Thereby, the word line 4 generated as explained above may be connected to the word line electrode pad 2C through the simplified alignment of the stamper 21. In Fig. 6, length in the right and left direction of cell area is reduced.

Subsequently, the data cell area 3 is subject to execution of uniform etching process from the surface of the ultraviolet-setting resin 20A to which the protruded 70 and recessed 72 areas are transferred (Fig. 5D), the metal layer 4A, pn silicon layer 6A and recording film 7A are removed from the recessed area 72 of the ultraviolet-setting resin 20A and the metal layer 4A, pn silicon layer 6A, recording film 7A are left for the protruded area of the ultraviolet-setting resin 20A (Fig. 5E). This etching process is executed by the dry-etching such as ion milling, plasma etching, RIE (Reactive Ion Etching), etc.

In this case, the layers up to the metal layer 4A may be removed by single etching process as required or the layers up to the metal layer 4A also may be removed by a plurality of times of etching process. Here, an excellent result may be obtained by setting the etching rates of ultraviolet-setting resin 20, metal layer 4A, pn silicon layer 6A and recording film 7A to almost equal rate and then setting the etching rate of the

memory substrate 2 to a very lower rate. In this case, selection ratio, stability and controllability of the etching may be improved by introducing different kinds of material into the material of the metal layer 4A.

Subsequently, for the data cell region 3, the interlayer insulating layer 8  
5 between the word lines 4 is generated as shown in Fig. 7 in the interlayer insulating layer generation process. Here, the interlayer insulating layer 8 is formed by vertical evaporation, for example, of  $\text{SiO}_2$ ,  $\text{Si}_3\text{N}_4$  to the substrate 2. Thereafter, any ultraviolet-setting resin 20A remaining on the recording film 7A and the  $\text{SiO}_2$  deposited on this  
10 ultraviolet-setting resin 20A are removed by the etching process so that the recording film 7A is exposed at the surface. Subsequently, in the data cell region 3, as shown in Fig. 8A, the interlayer insulating layer 8 above the bit line electrode pad 2B is removed by the photolithography in the bit line generation process.

The bit line 5 is generated like the word line 4. Moreover, in this case, the continuous pn silicon layer 6A and recording film 7A are isolated for the bit line 5  
15 direction and thereby data cell by the diode 6 and recording layer 7 is generated on the basis of so-called self-alignment.

Namely, in the data cell region 3, as shown in Fig. 8B, after the metal layer 5A is generated, the ultraviolet-setting resin is coated over metal layer 5A. Thereafter, as shown in Fig. 8C, the ultraviolet-setting resin 24 is hardened as a resin 24A because the  
20 stamper 25 is pressed, and the stamper 25 is peeled and thereby the protruded and recessed areas of stamper 25 are transferred so that a part of the bit line 5 is protruded. In this case, the bit line electrode pad 2B of stamper 25 is formed in remarkably loose period than the bit line 5 as in the case of the word line 4 and in a large area. Therefore, the word line 5 may be generated through more simplified alignment.

Subsequently, as shown in Fig. 8D, in the data cell region 3, the uniform etching process is executed from the surface of the ultraviolet-setting resin 24A to which the protruded and recessed areas of stamper 25 are transferred, the metal layer 5A is removed from the recessed area of the ultraviolet-setting resin 24A and the metal layer 5A is removed from the protruded area of the ultraviolet-setting resin 24 to form the bit line 5 (Fig. 8E). Moreover, for the recessed area of the ultraviolet-setting resin 24, the metal layer 5A and recording layer 7A formed of the lower layer of this metal layer 5A and the pn silicon layer 6A are removed and thereby the data cell area by the diode 6 and recording layer 7 is generated.

When the bit line 5 is generated as explained above, the data cell region 3 forms the interlayer insulating layer 8 as in the case of the word line 4. Thereby, the area between the bit lines 5 and area between data cells extending continuously in the direction to the word line 4 are insulated 8 and thereafter a protection film 9 is generated as a whole. As explained above, when the data cell region 3 is generated, a memory chip 1 is packaged through the inspection process.

The memory chip 1 is subjected to the scribing process chip by chip and is then packaged after a series of processes are executed on a plurality of memory substrates 2 formed continuously on the semiconductor wafer.

#### **(1-2) Operation of first embodiment**

In the structure explained above, this memory chip 1 (Fig. 1) allows formation of the system region 2A (Fig. 2), electrode pads 2B, 2C by techniques such as photolithography on the semiconductor wafer (Fig. 2) and thereby a plurality of memory substrates 2 are generated on a sheet of semiconductor wafer. Moreover, after the corresponding data cell region 3 is formed on each memory substrate 2 (Fig. 1), the





on the memory substrate 2, the ultraviolet-setting resin 20 is coated, and the protruded 70 and recessed 72 areas in the shape of word line 4 are formed by pressing the stamper 21 to this ultraviolet-setting resin 20 (Fig. 5C). With the uniform etching utilizing this protruded 70 and recessed 72 areas, the metal layer 4A, pn silicon layer 6A and recording film 7A are removed conforming to the protruded 70 and recessed 72 areas. Thereby, the word line 4, pn silicon layer 6A and recording film 7A deposited on this word line 4 may be formed.

Moreover, after the area between the word lines 4 is insulated by the interlayer insulating layer 8, a metal layer 5A is formed. In addition, the protruded and recessed areas of the bit line 5 shape may be formed by transfer process using the ultraviolet-setting resin 24 (Fig. 8B) and stamper 25 (Fig. 8C). With the uniform etching using such protruded and recessed area shape, the metal layer 5A, pn silicon layer 6A and recording film 7A may be removed and thereby the bit line 5 (Fig. 8E) may be generated. Simultaneously, the data cell formed of the diode 6 deposited between word line 4 and bit line 5 and the recording layer 7 are generated on the so-called self-alignment basis.

In these processes, the electrode pads 2C and 2B of the word line 4 and bit line 5 are formed very loosely on wider area in comparison with the word line 4 and bit line 5 (Fig. 6). Thereby, the word line 4 and bit line 5 may surely be connected to each electrode pad 2C and 2B by reducing the positioning accuracy at the time of pressing the stampers 21, 24. Accordingly, the data cell region 3 may be generated by as much simplified process.

Moreover, since the data cell region 3 itself may be generated by the thin film generating technique, transfer of protruded and recessed areas and etching process on

the memory substrate 2 in the wider area, the process and facility may be as much simplified.

In the memory chip 1 manufactured as explained above, the data cells are selected depending on the address by the system region 2A when data 62 (Fig. 3) is to be recorded, the recording layer 7 forming each data cell changes its crystal structure with the heating/cooling process depending on the logical level (Fig. 4). On the other hand, when data is to be read, a resistance value is detected by a current value depending on the voltage to be applied, where the resistance value changes depending on the crystal structure. Thereby, the desired data may be recorded and reproduced.

Accordingly, in the case of recording the desired data through change of resistance value due to change of the crystal structure of such recording layer 7, so-called refresh operation by the charge accumulation mechanism in the DRAM of related art may be omitted and the memory chip may be structured with the as much simplified structure.

### **(1-3) Effect of the first embodiment.**

According to the structure explained above, since the data cell region 3 is formed on the memory substrate 2 in which the system region 2A is manufactured, system region 2A may be produced on the memory substrate 2 and within the data cell region 3 using a design rule that is looser than that of the conventional art and thereby a larger capacity memory may be generated with so far simplified process.

Moreover, since the data cell region 3 is manufactured by a process that is different from the process of memory substrate 2, the data cell region 3 may be formed with a simplified process and, thereby, a large capacity memory may be generated with the more simplified process.

In more practical terms, since a data cell structure may be selected to record the desired data through change of resistance value due to the change of crystal structure of recording layer 7, the memory of a more simplified structure may be generated also with a more simplified process. In addition, since structure of a data cell may be more simplified than the semiconductor memory of related art by means of the charge accumulating mechanism, the large capacity memory also may be generated in as much simplified structure.

In addition, since the word line and bit line electrode pads 2C, 2B may be structured in remarkably wider area with looser period in comparison with the word line 4 and bit line 5, the positioning process may be more simplified.

## **(2) Second Embodiment**

In this embodiment, the present invention will be applied to a read only memory (ROM) rather than a memory that may be written as well as read (such as memory chip 1). Fig. 9 is a cross-sectional view showing a memory chip of this ROM. This memory chip 30 is formed by generating a data cell region 32 on the memory substrate 31.

Here, the memory substrate 31 is formed identical to the memory substrate 2 explained with reference to Fig. 2 and Fig. 3, except for the points that the input circuit 16 is omitted in the system region 31A (not shown) of the memory substrate 31 and the reproducing control signal 64A (not shown) is input in place of the recording/reproducing control signal 64.

Similar to the data cell region 3 explained in regards to Fig. 1, the data cell region 32 may include the word line 4, the bit line 5, and data cells disposed between the word line 4 and bit line 5. Each data cell is formed of a different structure depending on the logical level assigned to each data cell. For example, in the data cell

to which logical 0 is assigned, a diode 6 is arranged between the word line 4 and bit line 5. On the other hand, in the data cell to which logical 1 is assigned, the interlayer insulating layer 8 is arranged between the word line 4 and bit line 5. Thereby, the data cell may hold the data with a resistance and may detect data held by the current flowing when the predetermined voltage is impressed without a need for recording layer 7.

Figs. 10A-10E are cross-sectional views showing the generating process of word line 4 in the data cell region 32. This data cell region 32 forms, like the first embodiment, the metal layer 4A to the entire surface of the memory substrate 31 (Fig. 10A). Subsequently, the data cell region 32 also forms the pn silicon layer 6A.

Subsequently, the data cell region 32 is subjected to coating of the ultraviolet-setting resin 20 on the pn silicon layer 6A (Fig. 10B), and is then subjected to the depressing of stamper 34 (Fig. 10C). After the ultraviolet-setting resin 20 is hardened to a resin 20A under this condition, the stamper 34 is peeled. In this step of this embodiment, the stamper 34 is formed in the recessed shape corresponding to the thickness of word line 4 and pn silicon layer 6A in the data cell to which the logical 0 is assigned, while it is formed in the recessed shape corresponding to the thickness of word line 4 in area between the data cell to which the logical 1 is assigned and the data cell in the extending direction of the word line 4. Thereby, in the data cell 32, the protruded 74 and recessed 76, 78 areas of stamper 34 is transferred by the so-called photo-polymerization (2P) method and the protruded 80, 82 and recessed 84 areas by the ultraviolet-setting resin 20A are formed on the pn silicon layer 6A.

On the occasion of generating the protruded 80, 82 and recessed 84 areas by depressing the stamper 34, it is provided with the recessed areas 76, 78 at the depressing surface to form the protruded areas 80, 82 corresponding to the shape of

word line electrode pad 2C at the area overlapping with the word line electrode pad 2C as explained above in regard to Fig. 6. Therefore, the word line 4 may be connected to the electrode pad of the memory substrate 31 through the more simplified alignment.

Subsequently, in the data cell region 32, uniform etching process is executed from the surface of ultraviolet-setting resin 20A to which the protruded 74 and recessed 76, 78 areas are transferred as explained above (Fig. 10D). Accordingly, the metal layer 4A and the pn silicon layer 6A are removed for the deepest recessed area of the ultraviolet-setting resin 30. Thereby, the space 86 is formed between the continuous word lines 4. Moreover, the pn silicon layer 6A is removed for the next deepest recessed area and the metal layer 4A and pn silicon layer 6A are also removed for the protruded area of the ultraviolet-setting resin 20A (Fig. 10E).

Thereby, the continuous word line 4 is formed and a diode 6 is arranged in the data cell to which logical 0 is assigned and the word line 4 is formed to be exposed in the data cell to which the logical 1 is assigned.

Next an insulating film 88 of  $\text{SiO}_2$  or  $\text{Si}_3\text{N}_4$ , etc. is formed in the data cell region 32 and thereby insulation property between the word lines 4 is assured. As shown in Figs. 11A and 11B, after liquid resin, for example, of the ultraviolet-setting resin 36 is coated (Figs. 11A and 11B), the resin is hardened to provide the flat surface thereof. Subsequently, the ultraviolet-setting region 36 is etched by the etching method which does not give any influence on the metal layer 4A and pn silicon layer 6A, for example, such as the oxygen plasma etching, etc. (Fig. 11C) and thereby the surface of diode 6 which is protruded most from the memory substrate 31 may be exposed.

Thereby, in this embodiment, the interlayer insulating layer 8 is formed by the ultraviolet-setting resin 36. Moreover, in the data cell to which logical 1 is assigned,

the interlayer insulating layer 8 of the ultraviolet-setting resin 36 is formed on the word line 4. Thereby, in this memory chip 30 (Fig. 9), the bit line 5 is generated as in the case of the first embodiment so that the resistance value becomes almost 0 ohms [ $\Omega$ ] in the data cell of logical 0 and the resistance value becomes almost infinitive in the data cell of logical 1. In this case, the stamper 34 of memory chip 30 is positioned in the subsequent bit line generating process so that the bit line 5 is correctly formed on the surface of the exposed diode 6.

According to the structure shown in Fig. 9, the effect identical to the read/write memory first embodiment may be obtained by applying it to a read only memory (ROM).

### (3) Third Embodiment

In the third embodiment, each data cell is generated based on the 0/1 logical level of the data cell. Then, the bit line 5 is generated at the time of generating the word line 4. In the case of the second embodiment, higher accuracy is required for alignment of the bit line 5. Therefore, in this third embodiment, the bit line 5 is generated in the simplified alignment accuracy.

Namely, as shown in Fig. 12, the width of the data cell exposed so as to face the bit line 5 is defined as "W" and the repetition pitch of the data cell in the extending direction as "PW". In Fig. 12, the data cell exposing the diode 6 is indicated as the hatched areas. Moreover, as shown in Fig. 13, the line width of bit line 5 is defined as "B" and the repetition pitch as "PB". In this case, when the repetition pitch is defined as PW and it is assumed to be identical to PB, alignment accuracy of the line width B or less of the bit line 5 is required and the bit line 5 cannot be connected correctly to the data cell as shown in Fig. 14 depending on the simplified facility and process.

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In this embodiment, therefore, the stamper 90 to transfer the shape of bit line 5 is provided with the protruded 92 and recessed 94 areas at the surface thereof to assure the large area to form the bit line 5 surrounding the area of data cell. Thereby, if the stamper 90 is depressed with the loose alignment accuracy with reference to the electrode pad 2C, the protruded 92 and recessed 94 areas of the bit line 5 may be formed accurately in the area where the data cell is arranged.

Moreover, the stamper 90 is set to show the following relationship between the repetition pitch PW of the data cell and repetition pitch PB of the bit line 5 as shown in Fig. 15 and thereby the repetition pitch PB of the bit line 5 becomes smaller than the repetition pitch PW.

$$PW > PB \quad \dots\dots\dots (1)$$

Moreover, the stamper 90 is set to show the following relationship among the repetition pitch PW of data cell, width W of the data cell, repetition pitch PB of bit line 5 and width B of the bit line 5 and a certain word line 4 always overlaps on the data cell 6 arranged between these word lines in the adjacent word lines.

$$PB + B > PW - W \quad \dots\dots\dots (2)$$

Moreover, the stamper 90 is also set to show the following relationship among the repetition pitch PW of the data cell, width W of the data cell and width B of the bit line 5 and, therefore, the adjacent word lines 4 overlap on only one data cell.

$$PW - W > B \quad \dots\dots\dots (3)$$

Therefore, the memory chip of this embodiment is provided to surely connect the bit line 5 to each data cell by depressing the stamper 90 in the loose alignment accuracy with reference to the electrode pad 2B.

The stamper to form the word line 4 against the bit line 5 formed, as explained above, is provided with the protruded 92 and recessed 94 areas at the surface to record the reference data to the data cell in the specified area. For instance, this reference data may be recorded by forming the data cell in which the logical level of the particular pattern, for example, is continuous, on the predetermined word line.

The logical level of each data cell of this memory chip is inspected in the inspection process before delivery from the factory. Based on the inspection result, an offset value is given to the row address decoder 13 (Fig. 13). Thereby, relative displacement of bit line 5 is compensated with reference to this reference data.

According to the third embodiment, even when the read only memory is generated by generating the data cell simultaneously with the word line 4 formation, the read only memory may be manufactured through the simplified alignment.

#### **(4) Fourth Embodiment**

Fig. 16 is a cross-sectional view showing a memory chip in relation to the fourth embodiment. This memory chip 40 is generated by stacking the data cell substrate 42 on the memory substrate 2.

Here, the data cell substrate 42 is manufactured by forming, on a flat plate member such as silicon, glass and plastic, etc., the word line 4, data cell, bit line 5 in the same manner as explained in regard to the first and second embodiment. Moreover, the data cell substrate 42 is connected to the memory substrate 2 by the surface mounting method such as the micro solder ball, unisotropic conductive material and micro bump bonding, etc.



The effect similar to that of the first and second embodiments may be obtained by manufacturing the memory chip by stacking the data cell substrate 42 on the memory substrate 2.

#### **(5) Fifth Embodiment**

5 In this embodiment, after the word line 4, data cell and bit line 5 are formed on the data cell substrate 43 shown in Fig. 17, the memory chip by the random access memory is manufactured by stacking the memory substrate 2 as explained with reference to Fig. 16.

10 Namely, the data cell substrate 43 is manufactured by forming the groove 102 consisting of the protruded 104 and recessed 106 areas on the flat plate material of silicon, glass and plastic by the so-called photo-polymerization (2P) method or etching. The data cell substrate 43 also may be generated by the injection molding.

This groove 102 consisting of protruded 104 and recessed 106 areas is formed in such a manner that the protruded area 104 corresponds to the word line 4.

15 As shown in the cross-sectional view of Fig. 18 and Figs. 19A-B, in the data cell substrate 43, after the metal layer 4A (Fig. 19B) is formed by the evaporation from the upper diagonal direction, the pn silicon layer 6A and recording film 7A are sequentially formed. In this case, since the evaporation (Fig. 18) is performed from the upper diagonal direction, the evaporation material is almost not deposited at the shadow  
20 area 108 of the protruded area of the data cell substrate 43. Accordingly, the metal layer 4A, pn silicon layer 6A and recording film 7A are formed only at the upper surface of the protruded area 104 and the side surface of this protruded area 104. Thereafter, the data cell substrate 43 is subjected, for example, to the isotropic etching

such as wet etching to eliminate any evaporation material deposited in the shadow area 108 of the protruded area 104.

Thereby, the word line 4, pn silicon layer 6A deposited on the word line 4 and recording film 7A are formed in the data cell substrate 43 and then it is integrated with the memory substrate 2 through the interlayer insulating film 8 generating process of Fig. 7 and the bit line 5 and data cell generating process of Fig. 8.

According to this embodiment, the effect similar to that explained above may be obtained even when the word line 4 is formed conforming to the protruded 104 and recessed 106 shape formed on the substrate 43.

#### **(6) Sixth Embodiment**

Figs. 20A-C are cross-sectional views for explaining the word line 4 generating process as the sixth embodiment of the present invention. In this embodiment, the word line 4, pn silicon layer 6A and recording film 7A are generated by the process of Fig. 18 using the data cell substrate 43 explained in regard to Fig. 17.

Namely, in the data cell substrate 43, after the metal layer 4A is formed by evaporation from the upper direction, the pn silicon layer 6A and recording film 7A are sequentially formed (Fig. 20A). Thereafter, data cell substrate 43 is coated with the ultraviolet-setting resin and liquid resin 45 such as photoresist and the surface is flattened by hardening of the surface (Fig. 20B). Moreover, the etching process is executed in the film thickness direction to the data cell substrate 43. Thereby, the metal layer 4A, pn silicon layer 6A and recording film 7A are left at the recessed area of the data cell substrate 43 (Fig. 20C) and the word line 4 is formed in the data cell substrate 43 and the pn silicon layer 6A and recording film 7A are formed on this word line 4.

The data cell substrate 43 thereafter is integrated with the memory substrate 2, like the fifth embodiment, through the interlayer insulating layer 8 generating process shown in Fig. 7 and the bit line 5 and data cell generating process of Fig. 8.

According to this embodiment, the effect similar to that of the fifth embodiment may be obtained even when the word line 4 is formed in the recessed area of the data cell substrate 43.

### **(7) Seventh Embodiment**

In this embodiment, after the word line 4, data cell and bit line 5 are formed on the data cell substrate 47 shown in Fig. 21, a memory chip by the random access memory is generated by stacking the memory substrate 2 as is explained in regard to Fig. 16.

Namely, the data cell substrate 47 is manufactured by forming the protruded and recessed areas on the flat plate material such as silicon, glass and plastic by the so-called photo-polymerization(2P) method or etching. The data cell substrate 47 also may be manufactured by the injection molding.

In the data cell substrate 47, the protruded and recessed areas are formed in one direction corresponding to the repetition of word line 4 and moreover the protruded and recessed areas are formed corresponding to the repetition of the bit line 5 in the direction orthogonal to such one direction. Namely, in the area where both word line 4 and bit line 5 are not arranged, the deepest recessed area is formed. Moreover, at the area where the word line 4 and bit line 5 are overlapped, the protruded area is formed in the shallowest depth and the remaining area where only the word line 4 or bit line 5 is arranged is formed in the intermediate depth of such protruded and recessed areas.

In the data cell substrate 47, the metal layer 4A is generated by the evaporation from the upper diagonal direction orthogonal to the extending direction of the word line 4 and thereafter the pn silicon layer 6A and recording film 7A are sequentially formed.

In Fig. 22, deposition of the metal layer 4A, pn silicon layer 6A and recording film 7A are indicated as the hatched areas. In this case, any evaporation material is deposited in smaller amount at the area near the corner of the recessed area and at the area near the corner in the deeper side of the side surface of protruded area, in addition to the shadow area. In the data cell substrate 47, the evaporation material adhered to the shadow area of these recessed areas is completely removed by the isotropic etching such as wet etching. Thereby, the word line 4 is formed in the data cell substrate 47 and the pn silicon layer and recording film are then formed on the word line 4.

Subsequently, as shown in Fig. 23, the metal material is deposited, in the data cell substrate 47, by the evaporation from the upper diagonal direction orthogonal to the direction when the work line 4 is generated. In this case, the evaporation material becomes small in amount at the areas near the corner of recessed area, corner at the deeper area of the side surface of the protruded area, in addition to the shadow area.

Therefore, as shown in Fig. 24, in the data cell substrate 47, the word line 4 and bit line 5 are formed and the diode 6 by the pn silicon layer 6A and recording layer 7 by recording film 7A are formed at the protruded area where the word line 4 and bit line 5 are overlapping.

This data cell substrate 47 is integrated, after the evaporation material adhered to the shadow area of protruded area is completely removed, with the memory substrate 2, like the fifth embodiment, through the interlayer insulating layer 8 generation process of Fig. 7 and the bit line 5 and data cell generation process of Fig. 8.

According to this embodiment, the two-dimensional protruded and recessed areas are formed on the data cell substrate 43 and the effect similar to that of the fifth embodiment may be obtained even when the data line and word line 4 are formed following the protruded and recessed areas.

## 5 (8) Eighth Embodiment

Fig. 25 is a perspective view showing enlarged data cell substrate as the eighth embodiment of the present invention in comparison with Fig. 21. In this embodiment, a read only memory is manufactured using this data cell substrate 48.

10 Namely, in the data cell substrate 48, the protruded and recessed areas are formed corresponding to the word line 4 and bit line 5 as in the case of the seventh embodiment. In this case, the protruded area (which becomes a part of the data cell) is formed in such a manner that the data cell of logic 1 is in the data cell substrate 48. As explained above, the data cell substrate 48 is formed in different heights of protruded area depending on the logical level and the metal layer 4A and pn silicon layer 6A are  
15 generated like the seventh embodiment.

Namely, as shown in Fig. 26, the metal layer 4A is generated in the data cell substrate 48 by the evaporation from the upper diagonal direction orthogonal to the extending direction of the word line 4. Thereafter, the pn silicon layer 6A is formed. In this case, since the evaporation is conducted from the upper diagonal direction, the  
20 evaporation material is almost not deposited at the shadow area of the protruded area in the data cell substrate 48. Moreover, the evaporation material becomes small in amount in the area near the corner of the recessed area and the area near the corner of the deeper side of the side surface of the protruded area.

Particularly, the evaporation material is adhered in wider area at the side surface of the bit line side of the protruded area protruded in large amount because of assignment of the logic 0 by selecting the evaporation condition, but the evaporation material is adhered in smaller area at the side surface of the bit line side of the protruded area protruded in large amount because of assignment of logic 0. In this data cell substrate 48, any evaporation material adhered partially to the shadow area of the protruded areas may be eliminated perfectly by the isotropic etching such as the wet etching. Thereby, the word line 4 is formed in the data cell substrate 48 and the pn silicon layer 6A is then formed on this word line 4.

Subsequently, as shown in Fig. 27, the insulation film material is deposited by the evaporation from upper direction of the substrate surface to generate the insulating layer 49 in the data cell substrate 48. In this case, as shown in Fig. 28A showing the cross-sectional view along the line A-A, the insulating film material is deposited so that the metal layer 4A and pn silicon layer 6A are partially exposed at the side surface of the bit line side of the protruded area in large protrusion amount through assignment of logic 0 in the data cell substrate 48. Moreover, as shown in Fig. 28B showing the cross-sectional view along the line B-B, the insulating film material is deposited in the other area in such a manner that the surface is perfectly covered with the insulating layer 49.

Subsequently, the word line 4 is generated by the upper diagonal evaporation in the same manner as Fig. 23 in the data cell substrate 48 and thereby at the protruded area in large amount of protrusion to which logic 0 is assigned, the word line 4 and bit line 5 are held in the conductive condition sandwiching the diode 6 of the pn silicon layer 6A. At the protruded area in a small protrusion amount to which logic 1 is

assigned, the word line 4 and bit line 5 are kept in the non-conductive condition by the insulating layer 49 and thereby data cell setting the logical level may be generated.

The data cell substrate 48 is integrated with the memory substrate 2 after any evaporation material partially adhered to the shadow area of the protruded area is perfectly eliminated.

According to this embodiment, the two-dimensional protruded and recessed areas are formed in the height corresponding to the logical level in the data cell substrate 43 and the effect identical to that of the fifth embodiment may be obtained even when the data line and word line 4 are formed conforming to such protruded and recessed areas.

#### **(9) Other Embodiments**

In the third embodiment explained above, alignment error is compensated by setting of the bit line 5, but the present invention is not limited thereto and it is also possible to compensate such error, for example, with an error correction circuit.

Moreover, in the fifth to eighth embodiments explained above, the data cell substrate is separately structured in addition to the memory substrate, but the present invention is not limited thereto and it is also possible to form the data cell region on the memory substrate by forming the protruded and recessed areas on the memory substrate, for example, by the photo-polymerization(2P) method.

In addition, in the first to fourth embodiments explained above, the data cell region is formed on the memory substrate, the present invention is not limited thereto and it is also possible, on the contrary, to form the memory substrate on the data cell substrate. In this case, the system region is formed by a circuit using the TFT, etc.

Moreover, in the embodiments explained above, the data cell is generated simultaneously when the word line 4 is generated or the bit line 5 is generated, but the present invention is not limited thereto and then it is also possible to provide the data cell generating process to form the data cell in separation from the time when the word  
5 line 4 is generated or the bit line 5 is generated.

In addition, in above embodiments, the data cell, word line 4 and bit line 5 are arranged on the data cell substrate, but the present invention is not limited thereto and it is also possible to arrange, for example, a part of the selection mechanism to select the word line 4 and bit line 5 on the data cell substrate. Thereby, connection between the  
10 data cell substrate and memory substrate may be as much simplified.

Moreover, or in place of above, it is possible to arrange a TFT transistor to drive each data cell.

In addition, in above embodiments, the desired data is held in the data cell with a resistance value, but the present invention is not limited thereto and it is also possible  
15 to form the memory chip with a so-called FeRAM structure by forming, for example, a recording layer with the ferroelectric material film.

Moreover, in above embodiments explained above, the data cell region is formed conforming to the protruded and recessed areas by the stamper or conforming to the protruded and recessed areas of the data cell substrate, but the present invention is  
20 not limited thereto and it is also possible to apply the present invention to formation of the data cell region, for example, by the photoetching process using the mask.

Moreover, in above embodiments, the pn junction diode 6 is arranged in each data cell, but the present invention is not limited thereto and it is also possible to arrange the Schottky diode as required or to eliminate the diode.



Moreover, in the embodiments explained above, the data recorded to each data cell is reproduced by a current flowing when the predetermined voltage is applied, but the present invention is not limited thereto and it is also possible to reproduce data recorded in each data cell by detecting a voltage generated when the desired current flows.

In the embodiments explained above, the present invention is applied to a read only memory and random access memory, but the present invention is not limited thereto and it is also possible to generate a program memory which allows the recording operation only once by applying, for example, the material which changes non-inversely the composition to the recording film. Moreover, the present invention also may be applied to a memory including the read only memory, random access memory and program memory.

As explained previously, according to the present invention, a large capacity memory and an information apparatus using this memory may be manufactured with the simplified process by generating the data cell region with the process other than that for manufacturing the system region to control this data cell region.